A Novel Technique for Percutaneous Harvest of Calcaneal Autograft: Evaluation of Complications and the Effect on 1st MPJ and Lapidus Arthrodesis

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Statement of Purpose

The purpose of this poster is to present a novel technique for harvest of calcaneal bone graft, and to retrospectively evaluate potential complications with the harvest site. Calcaneal autograft is fairly documented in the medical literature, however formal analysis of complication rates and donor site morbidity is relatively lacking.

Introduction and Literature Review

Bone grafting is a common adjunctive procedure in orthopedic surgery often used for fusions, fracture repair and reconstruction of skeletal defects [1]. The foot and ankle are anatomical locations that not only benefits from bone grafts, but can at times carry the role of a donor site. Bone grafts typically are characterized as autograft or allograft based on the source of the donor. Autogenous bone grafts are historically the gold standard in foot and ankle reconstructive surgery [6]. These types of grafts must be transferred from one body site to another on the same patient. Autograft bone contains three important properties that are vital to bone healing, stimulation, and growth. It is osteoconductive, providing a scaffold for bone and fibrovascular tissues to proliferate. Its osteoinductive properties promote growth factors and matrix proteins which modulate cellular processes vital to bone growth. Lastly, it is osteogenic, as it provides osteoblasts, osteocytes, as well as precursors that will actively form new bone. Historically autograft bone provided all three properties, thus often considered as the gold standard of bone grafting [1]. In contrast, many commercial bone healing products, including allografts, were only osteoconductive and osteoinductive. Autografts can be cortical, corticocancellous, or simply cancellous [4]. There are multiple sites within the lower extremity that autografts can be harvested such as iliac crest, distal and proximal tibial metaphysis, and the calcaneus.

The calcaneus provides an excellent site for the harvest of graft due to its rich vascularity and cellularity as well as the fact it can provide the option to access corticocancellous or strictly cancellous bone depending on the specific graft indication [2,3]. The relatively thin soft tissue makes dissection comparatively easy compared to the more proximal harvest sites. Cancellous bone is typically used in areas that do not require significant structural support, such as filling small defects or applying to prepared joint surfaces to aid in the healing of joint fusions.

Adjunct use of autologous calcaneal cancellous grafts in forefoot arthrodesis has limited complications due the minimally invasive technique and small harvest amount. Various techniques have been described in the past, some with limitations. Biddinger et al in 1998 described a technique utilizing an 8mm round core biopsy. However, with this approach the medial and lateral cortices were purchased, increasing neurovascular insult, and iatrogenic fracture [2]. Roukis in 2006 described similar approach using this 8mm trephine, but without penetrating the medial cortex [5], similar limitation still exists with the lateral cortex, and need for specialized surgical instrumentation. DiDomenico and Haro in 2006, described a technique using a 3.5mm drill to penetrate the lateral wall then harvest cancellous bone with curettage to achieve desired amount of graft [3]. In the current study, we present a variation of the technique described by DiDomenico and Haro, including the results of utilizing the autograft for 1st MPJ and Lapidus arthrodesis procedures. This modified percutaneous technique for the harvesting of calcaneal cancellous bone autograft requires no additional surgical equipment or power instrumentation, thereby increasing operating room efficiency, and decreasing costs associated with allograft use. Hyer et al. previously reported pain levels and complications following percutaneous harvest of bone marrow aspirate from the calcaneus [7]. However, to our knowledge this is the first report of pain levels and complication rates following percutaneous harvest of autogenous calcaneal bone graft.

Figure 1: Instrumentation to perform modified percutaneous calcaneal bone graft harvest

QR Scanner links a video of the calcaneal graft harvest technique

Patients and Methods

After institutional review board approval, a retrospective medical record review was conducted on 34 consecutive patients who had undergone first metatarsophalangeal joint arthrodesis or Lapidus arthrodesis procedures with adjunct ipsilateral calcaneal cancellous autograft by the same board-certified foot and ankle surgeon from February 2016 to July of 2017. The surgeon routinely uses this technique for all forefoot arthrodesis procedures to fill voids and joint incongruities due to an in-situ joint preparation technique. Data was collected from the individual medical records by two independent reviewers (KR and NB) and consisted of laterality, age and sex of the patient, BMI, history of non-union risks (hematopoietic cancers, smoker, diabetes, chronic kidney disease, steroid use), post-operative pain levels (immediate, 6 weeks, 12 weeks), objective complications (Tinnel's sign of sural nerve, neuropraxia, wound breakdown/ infection, and hypertrophic scar). An independent and blinded board qualified foot and ankle surgeon reviewed plain film radiographic results for the heel (stress risers or iatrogenic fractures) and fusion sites (signs of radiographic union, or no signs of radiographic union) at the six and 12 week post-operative time periods. Data was organized and descriptive analysis performed using a commercially available spreadsheet. Complete data analysis was performed using a commercially available statistical program on a personal computer. Binary logistic regression analysis was used to calculate the odds ratio of nonunion using demographic information including, gender, age, laterality, smoking, diabetes, chronic kidney disease, hematologic cancer, and concomitant procedures. Confidence intervals were set to 95%.

Surgical Technique

The patient is placed in the supine position. A well-padded thigh tourniquet is used and typically inflated prior to graft procurement. If needed, a bump may be placed under the ipsilateral hip for better visualization of the lateral calcaneal region. The instrumentation necessary for adequate harvest includes: straight bone curettes, curved mosquito hemostat, #15 blade, sterile cup, and optional K-wire for fluoroscopic confirmation (Figure 1). The incision should be made inferior to the sural nerve and peroneal tendons on the posterolateral aspect of the heel. The incision is placed at the bisection of imaginary lines drawn between the distal tip of the fibula and posterior/inferior calcaneus and the cranial and caudal borders of the lateral calcaneus. Intra-operative fluoroscopy can assist with incision placement. It is vital that the harvest site be located within the midsubstance of the posterior tubercle of the calcaneus (Figure 2). This ensures a maximum amount of graft harvest while avoiding the important weight bearing architecture of the anterior and posterior calcaneus.

Figure 2: Utilization of a K-wire and fluoroscopy to assist with incision placement and graft harvest.

Once the site is located, a small stab incision is made parallel to the sural nerve with a #15 blade (Figure 3). The incision is carried down to the lateral wall of the calcaneus. A curved mosquito hemostat may be used if blunt dissection is necessary.

Next, a small straight bone curette is inserted into the lateral wall of the calcaneus. The curette is spun back and forth with the surgeon's fingers mimicking a "hand drilling" technique. Once the lateral wall is punctured the first curette is removed and a slightly larger curette is inserted and the process is repeated. Once a large enough curette is used (usually 4mm) the surgeon can safely harvest cancellous bone graft in an efficient manner. The surgeon must be able to visualize the three-dimensional orientation of the calcaneus within his or her mind's eye. Cancellous bone is then curetted utilizing an "ice cream scoop" technique, with care to not violate the medial calcaneal wall. Once cancellous bone is extirpated it is placed into a sterile container for later use at the fusion site (Figure 4). This harvest technique typically yields between 1-2 cc of cancellous autograft. Intra-operative fluoroscopy can be used to confirm harvest deficit if there is any concern for excessive cortical wall disruption (Figure 5).

Figure 3: Stab incision technique running parallel to the sural nerve to minimize risk of iatrogenic insult.

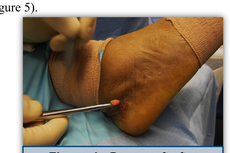

Figure 4: Bone graft after extirpation from the calcaneus.

Results

40 patients were initially identified as potential candidates for this retrospective cohort. Six patients had either failed to follow up or had incomplete charts, giving us a total of 34 patients for our study group. Our descriptive data was evaluated and noted to be nonparametric, therefore was reported with medians and ranges. Descriptive data is demonstrated in Table 1. In total 8 (23.53%) were male and 26 (76.47%) were female. The average age of our patient population was 54 (23, 69).The average body mass index (BMI) was 28.55 (20.8, 48.8). 16 (47.06%) cases were performed on the right lower limb and 18 (52.94%) were on the left. All patients underwent ipsilateral harvest of calcaneal bone graft (CPT 20900). The primary procedure performed were 1st MPJ arthrodesis 23 (67.65%) and Lapidus arthrodesis 11 (32.35). 21 (61.76%) of our patients were identified as having one or more known risk factors for development of non-union, with smoking 16 (47.06%) as the most prevalent. The outcome data for the primary objective of this study is highlighted in Table 2. Visual analog scale (VAS) pain scores were noted to be on average 3 (0,7), 0 (0,10), and 0 (0,0) for 2 weeks, 6 weeks, and 12 weeks post-operative respectfully. 3 (8.82%) patients experienced graft harvest site complications, including 1 (2.94%) wound infection/breakdown, 1 (2.94%) hypertrophic scar formation, and 1 (2.94%) neuropraxia of sural nerve. None of the patients demonstrated any abnormal plain film radiographic findings (stress riser, fracture, hypertrophic bone formation, etc.) as a result of the harvest. The overall mean rate of fusion (3 cortical bridges) was 30/34 (88.25%). Interestingly, smokers demonstrated a slightly higher fusion rate 15/16 (93.75%) than non-smokers 15/18 (83.33%), however once normalized for hardware failure secondary to early weightbearing both groups maintained a 93.75% fusion rate. The results of multivariate logistic regression analysis of fusion outcome and potential risk factors for non-union are demonstrated in Table 3. None of the risk factors demonstrated a statistically significant effect on the outcome of joint fusion.

Variable	Median (Range) or No. (%)
N = 34 Patients	
Sex	
Male	8 (23.53%)
Female	26 (76.47%)
Age	53 (23, 69)
< 37	7 (20.59%)
37 to 51 years	8 (23.53%)
51 to 65 years	17 (50.00%)
> 65 years	2 (5.88%)
Side Involved	
Right	16 (47.06%)
Left	18 (52.94%)
BMI	28.55 (20.8, 48.8)
Non-Union Risk Factors (Comorbidities)	
Hematopoietic Cancer History	0
Smokers	16 (47.06%)
Diabetes	4 (11.76%)
Chronic Kidney Disease	2 (17.65%)
Steroid Use	6 (17.65%)
Primary Procedure	
1st MPJ Arthrodesis	23 (67.65%)
Lapidus Arthrodesis	11 (32.35%)

Table 1: Descriptive Data of Patient Cohort

Outcome	Median (Range) or No. (%)	
Heel Pain VAS Scores		
Heel Pain 2 Weeks	3 (0, 7)	
Heel Pain 6 Weeks	0 (0, 10)	
Heel Pain 12 Weeks	0 (0, 0)	
Graft Harvest Site Complications	3 (8.82%)	
Wound Infection/Breakdown	1 (2.94%)	
Hypertrophic Scar	1 (2.94%)	
Tinnel's Sign / Neuropraxia of Sural Nerve	1 (2.94%)	
Abnormal Plain Film Xray Findings (stress riser, fracture, callous, etc.)	0 (0%)	
		Hardware Failure
Radiographic Joint Fusions	30/34 (88.25%)	30/32 (93.75%)
1st MPJ Arthrodesis	20/23 (86.96%)	
6 Weeks	9/23 (39.13%)	
12 Weeks	20/23 (86.96%)	
Lapidus Arthrodesis	10/11 (90.91%)	
6 Weeks	4/11 (36.36%)	
12 Weeks	10/11 (90.91%)	
Non-Unions	4/34 (11.76%)	2/32 (6.25%)
1st MPJ Fusion	3/23 (13.04%)	2/22 (9.09%)
Lapidus Arthrodesis	1/11 (9.09%)	0/10 (0%)
Smoker Fusions	15/16 (93.75%)	
1st MPJ Arthrodesis	10/11 (90.9%)	
Lapidus Arthrodesis	5/5 (100%)	
Non-Smoker Fusions	15/18 (83.33%)	15/16 (93.75%)
1st MPJ Arthrodesis	10/12 (83.33%)	10/11 (90.9%)
Lapidus Arthrodesis	4/5 (80%)	4/4 (100%)

Table 2: Outcome Data of Primary Investigation

Univariate Analysis of the Influence of Demographic Variables on the Outcome of Joint Fusion (N=34)				
Variable	**Sig.**	**Odds Ratio**	**95% C.I.for EXP(B)**	
			Lower	**Upper**
Smoker	0.213	17.226	0.195	1521.99
Additional Procedure	0.728	0.592	0.031	11.327
Sex	0.999	98367044.600	0.000	
BMI	0.328	1.124	0.889	1.420
Age	0.783	1.015	0.916	1.124
Diabetes	0.999	542917793.388	0.000	
CKD	0.999	34085800.120	0.000	
Steroid Use	0.135	0.035	0.000	2.851

Table 3: Multivariate Logistic Regression Analysis

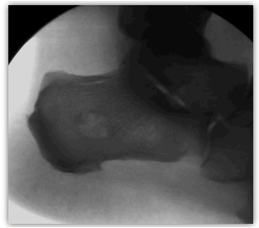

Figure 5: Radiographic evaluation of donor site.

Discussion

The main purpose of this study was to evaluate the safety of a highly utilized bone grafting technique in the foot and ankle: the calcaneal autograft. This technique provides a simple method for foot and ankle surgeons to utilize cancellous autograft for patients with small bony voids in forefoot fusion procedures. There are multiple advantages to using this technique. With the need for only basic surgical instrumentation, the surgeon can quickly and safely obtain graft thus improving efficiency in the operating room. Using an autogenous source of bone graft is cost effective, while also providing the patient with maximum benefits of a graft containing osteogenic, osteoconductive, and osteoinductive properties [1]. Although minimally invasive, it is a secondary procedure, and has risks of added complications. Potential complications include prolonged post-operative pain/swelling, numbness, scarring, and wound dehiscence/ infection at harvest site. Prior literature yielded minimal reported complications at the harvest site [4,5]. Hyer et al. reported pain levels after bone marrow aspiration and noted the calcaneus to be the most sensitive [7]. In our study we found a relatively low complaint of pain with an average VAS at 2 weeks post-operative of 3 and 0 at the final follow-up of 12 weeks. Additionally our harvest site complication rate was also extremely low. One of our patients was noted to have a wound infection at the two week mark, and was cured with oral antibiotics. One patient demonstrated a hypertrophic scar, but had no subjective complaints, and one demonstrated localized nerve irritation and was successfully treated with a corticosteroid injection.

The secondary aim of this investigation was to determine the effect of calcaneal bone autograft on two commonly performed procedures (1st MPJ arthrodesis and Lapidus arthrodesis). The non-union rates for both procedures have been previously well documented. Union rates for 1st MPJ arthrodesis have ranged from 88% to 96.18 % [8-14]. In 2011 Roukis authored a systematic review and meta-analysis which revealed an overall non-union rate of 94.6% [14]. In our patient population we noted a union rate of 86.96% of 1st MPJ arthrodesis patients, which does fall within range of previously published reports. Union rates for Lapidus arthrodesis procedures range from 93.5% to 97.8% [15-20]. Our patient population demonstrated a union rate of 90.9%.

Both of our procedure cohorts demonstrated a slightly smaller union rate as compared to historical data, however half of the patients that demonstrated non-unions did so as a result of early/prolonged weight-bearing and broken hardware. Once data was normalized to this finding our overall fusion rate was noted to be 93.75%.

The most peculiar finding of our study was the potential effect the bone graft had upon our patients with a smoking history. Overall the fusion rate amongst smokers was 93.75%. This was identical to the non-smoking cohort once normalized for broken hardware. Smoking has been implicated as a risk factor for non-union in a multitude of reports [8, 9, 13, 15, 17]. Although future prospective or possibly randomized controlled trials would be needed, it does appear that the use of calcaneal autograft may have an added benefit on joint fusion rates amongst smokers.

Based on the simplicity of the procedure, potential benefit of improving surgical outcomes, and low complication risk, this technique of calcaneal bone graft harvest can be advantageous to the foot and ankle surgeon.

CT Image of a Harvest Patient: Note the minimal amount of cortical wall disruption that the "ice cream scoop" technique provides. The medial cortical wall is also left untouched.

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